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A research on depth and flow velocity of intermittent debris flow

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In the flow of the open channel, the relationship between water depth and flow velocity is generally obtained in a state of steady and uniform flow. In steady and uniform flow, the acceleration term and advection term are neglected. Therefore, the external force on the fluid and the resistance force acting on the bottom of the flow come into equilibrium. In this state, the internal stress is modeled to obtain the relationship between water depth and flow velocity. The obtained result is widely used even when it is different from the preliminary steady and uniform flow. This is attributed to the difficulty of modeling the internal stress in the case of not steady and uniform flow.

A roll wave such as a debris flow is a flow having intermittent large water depth variation. The authors showed that the water depth fluctuation of such a flow is a kind of nonlinear wave phenomenon. In the process of deriving this nonlinear wave equation, from the homogeneous equation of $\epsilon^{1/2}$ order in the perturbation expansion of the basic equation, the following equation is obtained.

$$-\partial {\phi'}^{(1)}/\partial \xi' + {c_0'}^2 {\eta'}^{(1)} + \tan\theta c_0'/u_0' {\phi'}^{(1)} = 0$$

Here, subscript (1) represents the first term of perturbation expansion. ${\phi'}^{(1)} = \phi^{(1)}/(h_0 v_{p0})$: dimensionless velocity potential, ${\eta'}^{(1)} = \eta^{(1)}/h_0$: dimensionless variable component from mean depth, $\xi = \epsilon^{1/2}(x - v_{p0}t)$, $\xi' = \xi/h_0$, $c_0' = c_0/v_{p0}$, $c_0 = \sqrt{gh_0\cos\theta}$: long wave celerity, h_0 : mean depth, $u_0' = u_0/c_0$, u_0 : mean velocity, θ : slope angle of the channel, g : acceleration due to gravity, x : coordinates in the flow direction, t : time.

Since the above equation can be regarded as an ordinary differential equation, it is solved the above equation for ${\phi'}^{(1)}$. Consider the possible range of parameters. And the derivatives of phi can be approximated as follows.

$$\partial {\phi'}^{(1)}/\partial \xi' = {c_0'}^2 {\eta'}^{(1)}$$

$\partial {\phi'}^{(1)}/\partial \xi'$ represents the flow velocity component $u_1' = u_1/c_0$ in the x direction. From these facts, the relationship between velocity $u = u_0 + u_1$ and flow depth $h = h_0 + \eta$ is as follows.

$$u = u_0 + {c_0'}^2 c_0 (h/h_0 - 1)$$

The relationship between velocity and flow depth of roll wave has a linear relationship.